

# Force Sensor (7A)

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- Force Sensor
- Torque Sensor
- Tactile Sensor

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# Measuring Force

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## Acceleration

$$a = \frac{F}{m}$$

## Pressure

$$P = \frac{F}{A} \quad (A: \textit{area})$$

## Acceleration

$$\tau = FL \quad (L: \textit{Lever arm})$$

# Stress and Strain

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## Normal Stress

- **tensile stress**
- **compressive stress**

## Normal (Longitudinal) Strain

- **tensile strain**
- **compressive strain**

## Lateral Strain

## Shearing Strain

## Tangential Strain

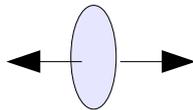
# Stress

## Normal Stress

$A =$  cross section area

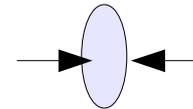
$F =$  force

- tensile stress



$$\sigma = +\frac{F}{A}$$

- compressive stress



$$\sigma = -\frac{F}{A}$$

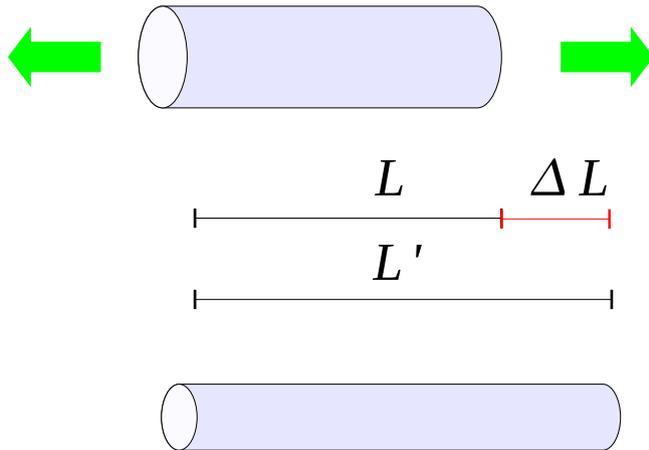
# Strain

## Normal Stress

$A =$  cross section area

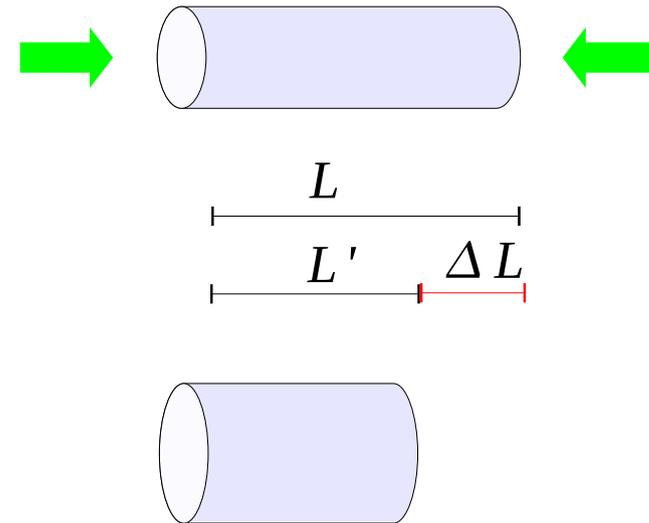
$F =$  force

- **tensile strain**



$$\epsilon = +\frac{\Delta L}{L}$$

- **compressive strain**



$$\epsilon = -\frac{\Delta L}{L}$$

# Strain Gage

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$$R = \rho \frac{L}{A}$$

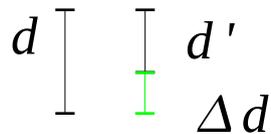
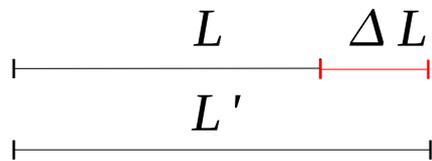
## **Metal Strain Gauge**

- **wire type**
- **foil type**
- **thin film**

## **Semiconductor Strain Gauge**

**Piezo-resistive effect**

# Strain Gage



$$L \rightarrow L + \Delta L$$

$$d \rightarrow d - \Delta d$$

$$R = \rho \frac{L}{A}$$

$$\frac{\Delta R}{R} = \left[ \frac{\Delta R}{R} \right]_{\epsilon} + \left[ \frac{\Delta R}{R} \right]_T$$

$$\begin{aligned} \frac{dR}{R} &= \left[ \frac{dR}{R} \right]_{\epsilon} + \left[ \frac{dR}{R} \right]_T \\ &= \frac{1}{R} \left[ \frac{\partial R}{\partial L} \frac{\partial L}{\partial \epsilon} + \frac{\partial R}{\partial A} \frac{\partial A}{\partial \epsilon} + \frac{\partial R}{\partial \rho} \frac{\partial \rho}{\partial \epsilon} \right] d\epsilon \\ &\quad + \frac{1}{R} \left[ \frac{\partial R}{\partial L} \frac{\partial L}{\partial T} + \frac{\partial R}{\partial A} \frac{\partial A}{\partial T} + \frac{\partial R}{\partial \rho} \frac{\partial \rho}{\partial T} \right] dT \end{aligned}$$

$$\frac{\Delta R}{R} \approx \frac{dL}{L} - \frac{dA}{A} + \frac{d\rho}{\rho}$$

# Load Cell

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## Beam: spring element

- **Bending beam**
- **Shear beam**
- **Canister beam**
- **Ring-type beam**
- **Helical beam**

# Torque Sensor

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**Moment**

**Torque**

- **rigid body**
- **shear strain**
- **twist angle**

**Strain gauge type**

**Optical type**

# Tactile Sensor

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**Touch Sensor**

**Tactile Sensor**

**Slip**

- **resistive**
- **piezo-electric**
- **optical**

## References

- [1] <http://en.wikipedia.org/>
- [2] Nam Ki Min, Sensor Electronics, Dong-il Press